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GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT OF THE SAN LUIS AREA, NEW MEXICO

BY

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GEOLOGY, ENERGY AND MINERAL RESOURCES
ASSESSMENT OF THE SAN LUIS AREA,
NEW MEXICO
by

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SUMMARY

This report is a preliminary assessment of the "Geological, Energy and Mineral Resources" (GEM) of the San Luis Area (GRA) in Sandoval and McKinley Counties, northwestern New Mexico. The area contains six Wilderness Study Areas (WSAs) all of which are located in the southeast part of the San Juan Basin, west of the Nacimiento Mountains. The total WSA acreage is 79,552 acres (321.77 km²).

The dominant geological features of this GRA are the Nacimiento uplift on the east edge of the area and the southeast flank of the San Juan Basin (east end of the Chaco Slope). The western two-thirds of the GRA is occupied by the mesas and volcanic plugs, with intervening partially dissected plains and arroyos.

The known mineral deposits in the San Luis area are petroleum (three shallow oil fields), subbituminous coal in the Mesaverde Group, extensive reserves and resources of gypsum, uranium, humate (soil conditioner), and sand and gravel. The area contains an unusual geological resource, the underground natural gas storage facility near San Ysidro. Other similarly favorable structures for gas storage may exist in the area.

Additional known prospects and occurrences include coal, copper/silver, uranium, humate, gypsum, petroleum, and sand and gravel. The area is currently being explored for all these commodities, especially coal, uranium, and petroleum.

Within the six WSAs the most favorable classifications for GEM resources are:

- a. Gypsum (classification 4-C) in the part of the Ojito WSA where the gypsum unit of the Todilto Formation is present in outcrops or with less than 200 feet of overburden.
- b. Coal (classification 4-C) in the parts of La Lena, Empedrado, Chamisa, and Ignacio Chavez WSAs where the Cleary Member of the Menefee Formation is present in the outcrop or at shallow depth.
- c. Uranium (classification 4-D) in the part of the Ojito WSA where the Brushy Basin and Westwater Canyon Members of the Morrison Formation are present in outcrop or at shallow depth.

Additional work is recommended to improve the assessments for uranium, copper/silver, oil and gas, coal and humate, and sand, gravel and aggregate. Specifically, further work should include:

1. Stronger efforts should be made to obtain privately held geological data directly relevant to the study areas and objectives,
2. Geophysical and driller's logs should be purchased and interpretation should be performed,
3. At least reconnaissance-level field investigations, including investigation of ore-controlling factors, should be performed in each WSA,
4. Detailed geologic mapping and detailed multi-media geochemical sampling would also be necessary.

INTRODUCTION

This report is one of a series prepared by Geoexplorers International, Inc. for the U.S. Bureau of Land Management (BLM) as part of the program for assessment of known and potential resources in previously designated Wilderness Study Areas (WSAs) in New Mexico. As required by the BLM, preliminary assessments have been made of the potential for Geological, Energy, and Mineral Resources (GEM) in the subject area. The methodology used in this study is as follows:

1. a search for and assemblage of available unpublished and published information on the designated WSAs and the surrounding areas,
2. grouping of the WSAs into Geological Resource Areas (GRAs), taking into consideration the local and regional geological settings and the requirements of the BLM reporting format,
3. identification of the geological environments favorable for the occurrence of energy and mineral resources in each GRA,
4. limited field verification in areas selected jointly by BLM representatives and Geoexplorers,
5. reinterpretation of the data base needed as the result of the field work,
6. land classification for GEM resources potential in the areas studied, including assessments of favorability and of the level of confidence in each WSA.

The assessments are preliminary, designated by the BLM as Phase One to be followed with more detailed investigation. The total effort expended by Geoexplorers on the study of this GRA was about 4.0 man-months.

In this report, resources are defined as mineral or fossil fuel deposits amenable to economic development under current or reasonably anticipated conditions. The terminology is consistent with the usage of the U.S. Bureau of Mines and the U.S. Geological Survey (1980; 1976). Included in resources are:

1. known reserves (measured, indicated and inferred),
2. deposits currently known to exist but not currently recoverable because of either technological or economic constraints, and
3. deposits not currently known, but for which favorable geologic environments can be demonstrated.

The San Luis GRA is located mostly in the western part of Sandoval County and extends about ten miles into southeastern McKinley County, New Mexico (see index map, fig. 1). The area is in the Albuquerque 1:250,000 quadrangle. The principal access to the area is by light duty roads and unimproved roads leading westerly from State Highway 44 between the towns of San Ysidro and Cuba. The village of Guadalupe is in the south-central part of the GRA, and La Ventana is two miles north of the northern edge. Included in this GRA are six WSAs with a total of 79,552 acres (321.79 km²). The WSAs are administered by the Albuquerque BLM district and have been designated in the BLM Wilderness Inventory as follows:

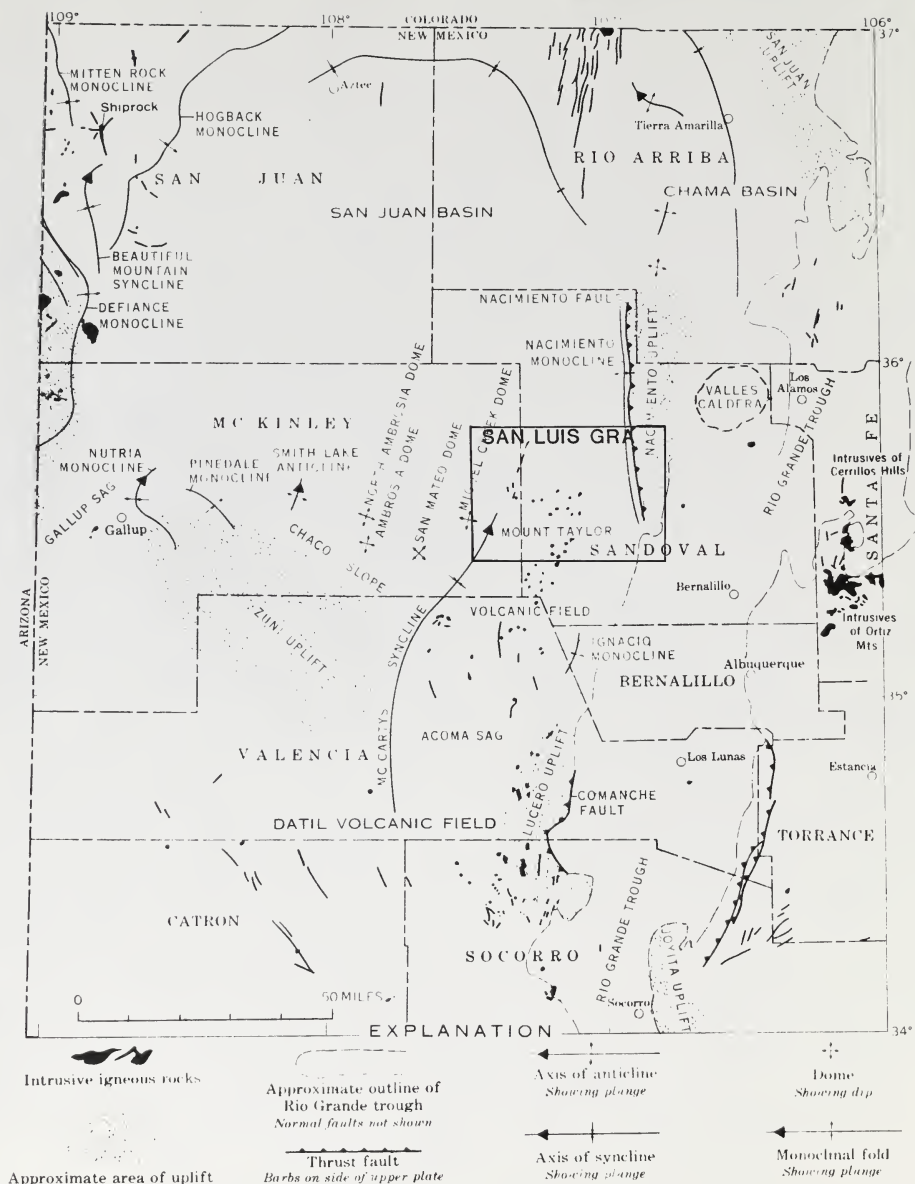


FIG. 1. PRINCIPAL STRUCTURAL ELEMENTS IN NORTHWESTERN NEW MEXICO. From Hilpert (1969) p.27. (San Luis GRA outlined).

TABLE 1: Wilderness Study Areas in the San Luis GRA

WSA no.	WSA Name	Acres	km ²
NM-010-020	Ignacio Chavez	32,248	130.44
NM-010-021	Chamisa	11,091	44.86
NM-010-022	Cabazon	7,235	29.26
NM-010-024	Ojito	11,200	45.30
NM-010-063	Empedrado	8,419	34.05
NM-010-063A	La Lena	<u>9,359</u>	<u>37.86</u>
Total		79,552 acres	321.77 km ²

The WSAs and the surrounding areas are shown on the map to the scale of 1:250,000 (in figures 2 and 4-11).

PHYSIOGRAPHY

Most of the San Luis GRA is located on the eastern edge of the Colorado Plateau physiographic province. The small part of the area east of the Nacimiento Mountains is located within the Southern Rocky Mountains Province. The Nacimiento fault marks the eastern edge of the Colorado Plateau and of the San Juan Basin. East of Mesa Prieta, including Bernalillito Mesa and White Mesa, is part of the Rio Grande trough and, therefore, is located in the Basin and Range physiographic province.

The area is drained by tributaries of the Rio Puerco and the Rio Salado, both of which drain southeasterly toward the Rio Grande, with the Rio Puerco reaching the Rio Grande at a point about 50 miles south of Albuquerque. The Rio Salado joins the Jemez River near San Ysidro and then flows to the Rio Grande.

The highest altitudes in the San Luis GRA are in its northeast and southwest parts. The highest peaks, over 9,000 feet above mean sea level,

are in the Nacimiento Mountains in the northeast part of the GRA. The lowest elevation is about 5,400 feet, near San Ysidro. In the southwest, the highest elevations are on Mesa Chivato at about 8,000 feet. The very prominent Mt. Taylor (11,301 feet) is located 15 miles southwest of this GRA. Most of the central and western parts of the area are flatter, with average elevations between 6,000 and 7,000 feet; but there are isolated peaks above 7,000 feet, the highest of which are Cabezon Peak (7,785 feet) and on Mesa Prieta (7,522 feet).

GEOLOGY

Lithostratigraphy - Rock Units

The rock units exposed in the San Luis GRA range in age from Precambrian to Quaternary. Precambrian granitic and gneissic rocks are exposed in the Nacimiento Mountains, flanked by Paleozoic and Mesozoic sediments (progressively younger toward the west into the San Juan Basin). Tertiary extrusive volcanic rocks are found as mesa cappings on Mesa Prieto and Mesa Chivato. Intrusive volcanic stocks and plugs of Cretaceous to Tertiary age are exposed in the central, south, and southwest parts of the area.

The oldest sedimentary rocks in this area are Mississippian carbonates of the Arroyo Penasco Formation. These rocks are exposed only as a few isolated erosional remnants in the Nacimiento Mountains, in areas too small to show on the 1:250,000 geologic map. More widely exposed are sediments ranging in age from Pennsylvanian to Upper Cretaceous, dipping generally toward the west away from the Nacimiento Mountains. In the subsurface, rocks of Cambrian and Devonian ages have been drilled in the northwest part of the San Juan Basin but do not extend as far southeast as this area. Ordovician and Silurian rocks have not been found in this part of New Mexico.

Figure 3. **LEGEND**
FOR

GEOLOGIC, ENERGY AND MINERAL RESOURCES MAPS

Scale of all maps is 1:250,000 or as otherwise indicated.

LITHOSTRATIGRAPHY

Mainly after C.H. Dane and G.O. Bachman, 1965

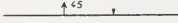
QUATERNARY	HOLOCENE	Qal	ALLUVIUM
	PLEISTOCENE	QTp	PEDIMENT - terrace, and other deposits of gravel, sand and caliche
	MIOCENE	QTs	SANTA FE GROUP - undivided. Fluvial, brown, buff, gray sandstone, mudstone
Tb		Andesite and basaltic andesite flows, breccias, and tuff	
Ti		INTRUSIVE ROCKS OF TERTIARY AGE	
TERTIARY	UPPER	Kl	LEWIS SHALE
		Kch	CLIFF HOUSE SANDSTONE - includes La Ventana Tongue (Klv)
		Kmf	MENEFEE FORMATION - Shale, sandstone and important coal beds
		Kpl	POINT LOOKOUT SANDSTONE - includes the Hosta Tongue (Kh)
		Kcc	CREVASSE CANYON FORMATION - Sandstone, shale and some coal
		Kg	GALLUP SANDSTONE - Includes some coal
		Km	MANCOS SHALE including the Satan (Kms) and Mulatto (Kmm) Tongues of the Mancos Shale extended into younger rocks of the Mesaverde Group
		Kd	DAKOTA SANDSTONE
CRETACEOUS			

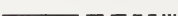
JURASSIC		Jm	MORRISON FORMATION - Sandstone, mudstone, and shale; gray, buff, and maroon
		Jsr	SAN RAFAEL GROUP - includes Summerville, Todilto Limestone and gypsum, and Entrada Sandstone
TRIASSIC		Tc	CHINLE FORMATION - Sandstone, shale, and some conglomerate
P E R M I A N	LEONARDIAN	P	PERMIAN ROCKS - undivided
		Psg	GLORIETA SANDSTONE
	WOLFCAMPIAN	Pa	ABO SANDSTONE - Mudstone and arkosic sandstone; dark gray and red
PENNSYLVANIAN		Pms	MADERA LIMESTONE and SANDIA FORMATION - undivided
PRECAMBRIAN		pC	PRECAMBRIAN ROCKS - undivided; mainly granite, granite gneiss, quartz monzonite gneiss

SPECIAL SYMBOLS OF STRUCTURAL FEATURES

After U.S. Geological Survey

 Contact – Dashed where approximately located; short dashed where inferred; dotted where concealed

 Contact – Showing dip; well exposed at triangle

 Fault – Dashed where approximately located; short dashed where inferred; dotted where concealed

 Fault, showing dip – Ball and bar on downthrown side

 Normal fault – Hachured on downthrown side

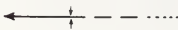
 Fault – Showing relative horizontal movement

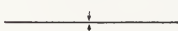
 Thrust fault – Sawteeth on upper plate

 Anticline – Showing direction of plunge; dashed where approximately located; dotted where concealed

 Asymmetric anticline – Short arrow indicates steeper limb

 Overturned anticline – Showing direction of dip of limbs

 Syncline – Showing direction of plunge; dashed where approximately located; dotted where concealed

 Asymmetric syncline – Short arrow indicates steeper limb

 Overturned syncline – Showing direction of dip of limbs

 Monocline – Showing direction of plunge of axis

 Minor anticline – Showing plunge of axis

 Minor syncline – Showing plunge of axis

Strike and dip of beds – Ball indicates top of beds known from sedimentary structures

 70° Inclined  Horizontal
 Vertical  40° Overturned

Strike and dip of foliation

 20° Inclined  Vertical  Horizontal

Strike and dip of cleavage

 15° Inclined  Vertical  Horizontal

Bearing and plunge of lineation

 15° Inclined  Vertical  Horizontal

Strike and dip of joints

 40° Inclined  Vertical  Horizontal

Note: planar symbols (strike and dip of beds, foliation or schistosity, and cleavage) may be combined with linear symbols to record data observed at same locality by superimposed symbols at point of observation. Coexisting planar symbols are shown intersecting at point of observation.

SPECIAL SYMBOLS

FOR ENERGY AND MINERAL RESOURCES

KNOWN DEPOSITS AND OCCURRENCES

 -O Oil field	 -C Coal deposit	 -Mineral orebody - as specified with symbol
 -G Gas field	 -C Coal occurrence	 -Mineral deposit - as specified with symbol
 -Os Oil shale		 -Mineral occurrence - as specified with symbol
		 -Mineral district (Fig.=inserted map)

EXPLORATION AND/OR MINING ACTIVITY

MINERALS AND COAL

 Mineral deposit, mine or prospect with recorded prod.	 Vertical shaft	 Active gravel or clay (cl) pit
 Prospect or mine with no recorded production	 Inclined shaft	 Inactive gravel or clay (cl) pit
 Accessible adit, or tunnel	 Active open pit, or quarry	 Exploration hole with data available
 Inaccessible adit, or tunnel	 Inactive open pit, or quarry	 Exploration hole without data
		 Mining district (Fig.=inserted map)

PETROLEUM

 Oil well	 Show of gas	 CO ₂ - or He-helium- rich well
 Oil and gas well	 Show of oil	 Dry well - abandoned
 Gas well	 Show of oil and gas	
	 Shut-in well	

GROUND WATER

 Water well of special importance	 Brine	 Thermal water
 Water well of high yield	 Mineral water	 Radioactive water
 Flowing water well		 Thermal point

ENERGY RESOURCES

O Oil	C Coal	U Uranium
G Gas	Cb Lignite (brown coal)	Th Thorium
Os Oil shale	Cp Peat	Gt Geothermal
Ot Tar sands		

MINERAL RESOURCES

METALS

Al Aluminum	Cu Copper	Mo Molybdenum	Tl Thallium
Sb Antimony	Ga Gallium	Ni Nickel	Sn Tin
As Arsenic	Ge Germanium	Nb Niobium or Columblum	Ti Titanium
Be Beryllium	Au Gold	Pt Platinum group	W Tungsten
Bi Bismuth	Fe Iron	RE Rare earth	V Vanadium
Cd Cadmium	Pb Lead	Re Rhenium	Zn Zinc
Cr Chromium	Li Lithium	Sc Scandium	Zr Zirconium and Hf Hafnium
Cs Cesium	Mn Manganese	Ag Silver	
Co Cobalt	Hg Mercury	Te Tellurium	

NONMETALS - INDUSTRIAL MINERALS

ab Abrasives	di Diatomite	fs Feldspar	mg Magnesian refractories
al Alum	Nonmarine and marine evaporites and brines	F Fluorite (fluorspar)	mi Mica
as Asbestos	pt Potash	gs Gem stones	ph Phosphate
ba Barite	na Salt - mainly halite	ge Graphite	pi Pigment and fillers
be Bentonite	gy Gypsum and anhydrite	He Helium	qz Quartz crystals
ca Calcite	nc Sodium carbonate or sulfate	kl Kaolin	sl Silica sand
cl Clay	bn Boron minerals	ky Kyanite and related minerals	S Sulfur
Construction materials:	nl Nitrates	ls Limestone	tc Talc
cs Crushed stone	Sr Strontium	lm Lithium minerals	ze Zeolites
la Lightweight aggregates, includ.:	Br Bromine		hm Humate
pm Pumice and volcanic cinders	cc Calcium chloride		
pe Perlite	mg Magnesium compounds		
ec Expanded clay, shale, slate			
vm Vermiculite			
sg Sand and gravel			
cr Cement raw materials			
bs Building stones			
li Lime			

SPECIAL GEOLOGICAL FEATURES

POINT OF SPECIAL GEOLOGIC INTEREST

m Mineral occurrence	s Structural, bedding, foliation, etc.,	u Radioactive spring
f Fossil locality	b Brecciation, shear zone, etc.,	g Thermal spring
v Volcanic phenomenon	y High yield spring	a Extensive rock alteration
t Stratigraphic sequence	p Spring with mineral water	r Lithologic type locality

FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE FOR MINERAL RESOURCES

FAVORABILITY:

- 1A - Undefined
 - 1 - Not favorable - combine with either B, C, or D
 - 2 - Low
 - 3 - Moderate
 - 4 - High
- } combine with either A, B, C, or D

LEVEL OF CONFIDENCE:

- A - Insufficient data
- B - Indirect evidence
- C - Direct evidence
- D - Abundant direct and indirect evidence

Precambrian

The depth to the Precambrian basement rocks is about 8,000 feet in the northwest part of the GRA and the sedimentary section thins to the east and south. In the vicinity of the Nacimiento fault, Pennsylvanian, Permian and Triassic rocks crop out, and east of the fault in the Nacimiento Mountains Precambrian granitic and gneissic rocks are exposed on the surface. Locally there is a thin veneer of sedimentary rocks and a few small areas with younger volcanics.

Mississippian

Arroyo Penasco Formation

The Arroyo Penasco Formation is a Mississippian carbonate unit, known only from a few scattered outcrops in the Nacimiento Mountains where it rests directly on the Precambrian crystalline rocks. The upper part is Meramecian in age and the lower part is Osagean. The preserved thickness is up to 150 feet of cherty, crystalline limestone mainly light gray to white in color. Some exposures are weathered or stained to shades of pink, red, or brown, and some weathered exposures have solution cavities up to two inches across. The unit is probably present in the subsurface in some of the area west of the Nacimiento fault, but is absent in the Central San Juan Basin.

Pennsylvanian

Sandia Formation

The Sandia Formation is of Middle Pennsylvanian age, probably mostly Atokan. The unit is mainly dark sandy shale with smaller amounts of sandstone and earthy limestone. It unconformably overlies the Arroyo Penasco Formation and Precambrian rocks. The unit is about 100 feet thick along the Nacimiento front in the northeast part of the San Luis GRA, and probably reaches thickness of 200 feet in parts of the area. The Sandia is

conformably overlain by carbonates of the Madera Limestone.

Madera Limestone

The Madera Limestone is about 700 feet thick in the San Luis GRA and consists of gray cherty limestone, with a greater percentage of mudstone and arkosic sandstone near the top. The lower part is sometimes called the Lower Gray Limestone and is probably Desmoinesian in age. The upper, more arkosic, part is Missourian.

Permian

Abo Formation

The Permian (Wolfcampian) Abo clastic section overlies the Madera and is about 700 feet thick in this area. The Abo Formation is mainly dark red and gray mudstones and interbedded lenticular sandstones. Its age is Wolfcampian, and possibly Leonardian in part at the top. The Abo correlates with the lower part of the Cutler Formation of the northwestern San Juan Basin.

Yeso Formation

The Yeso Formation of Permian (Leonardian) age is a brighter orange-red than the underlying Abo Formation. The Yeso consists of a fluviatile sand unit, mostly massive or crossbedded, with minor interbedded siltstone and limestone. It is variable in thickness, but in this area averages about 200 feet thick.

Glorieta Sandstone

The Glorieta Sandstone overlies the Yeso Formation and is also of Leonardian age. Also a quartzose sand unit, it is lighter in color than the Yeso. The Glorieta is about 100 feet thick in this area. The Bernal Formation and San Andres Limestone overlie the Glorieta in areas to the south

and east, but are absent in the immediate area of the San Luis GRA.

Triassic

Chinle Formation

The Chinle Formation of Late Triassic age overlies the Glorieta Sandstone. Three members of the Chinle Formation are recognized in this report. From base to top they are the Agua Zarca Sandstone Member, the Salitral Shale Member, and an upper Shale Member. The total thickness of the Chinle Formation ranges from about 1000 to 1200 feet. The basal Shinarump Member, which is an important host for uranium ore in the Four Corners area, is not recognized in the San Luis GRA. The Agua Zarca Member (up to 300 feet thick) is approximately equivalent, and is important as the major host for copper-silver deposits in the Cuba area. The Agua Zarca is a light buff quartzose sandstone, medium to coarse grained, with some conglomerate and minor shale. Like the Shinarump, it has prominent conglomeratic channels with abundant carbonaceous debris, including fossil logs, and in many places the woody material has been replaced by ore minerals. Above the Agua Zarca is the reddish-maroon Salitral Shale Member (300 feet) and an unnamed upper member of shale, siltstone, and sandstone approximately equivalent to the Petrified Forest Member (600 feet).

Jurassic

Entrada Sandstone

In the San Luis GRA, the Entrada Sandstone is the basal formation of the San Rafael Group, resting on the Triassic Chinle Formation. The Entrada, a light buff to white, fine to medium grained quartz sandstone, is 150 feet thick. The Entrada contains minor feldspar and many frosted quartz grains indicating eolian deposition. The lower part is silty and the upper part, a more well-sorted sandstone, makes up most of the formation thickness in this

area. There are many small uranium deposits in the Entrada Sandstone in the Ambrosia Lake and Laguna districts. Occurring mostly near the top of the formation, they are associated with uranium ore deposits in the (overlying) basal limestone unit of the Todilto Formation. The Entrada Sandstone itself is not a favorable host rock for uranium deposits.

Todilto Formation

The Todilto rocks were originally named as the Todilto Limestone (Gregory, 1917). However, the term Todilto Formation has been commonly used because in the eastern San Juan Basin the Todilto rocks are mostly gypsum and anhydrite (Santos, 1975). The Todilto Formation conformably overlies the Entrada Sandstone. In the San Luis GRA the Todilto is made up of a thin basal limestone unit, 5 to 20 feet thick, and an upper unit of evaporite, 50 to 90 feet thick. The total formation thickness is 60 to 100 feet. Gypsum is the evaporite unit near the outcrop area and anhydrite is the evaporite unit elsewhere.

Summerville Formation

Conformably overlying the Todilto is the Summerville Formation, which in the San Luis GRA and vicinity is the upper unit of the San Rafael Group. The Summerville is fine-grained sandstone and mudstone and is brown to gray in color. The average thickness in the San Luis GRA is about 100 feet, with thickness ranging from 50 feet in the north part of the GRA to 150 feet in the south part. The unit is absent north of latitude 35 degrees 45 minutes N (Green, et al., 1980; Santos, 1975).

Morrison Formation

In southeastern San Juan Basin, the Morrison Formation conformably overlies the Summerville Formation and consists of, in ascending order, the

Recapture Member, Westwater Canyon Member, and Brushy Basin Member. The three members are mostly conformable, with gradational contacts common. Only locally are erosion surfaces developed separating the members (Santos, 1975,). The upper part of the Brushy Basin Member is the Jackpile sandstone which, although not a formally named unit, is widely recognized and very important as the host for major uranium ore bodies in the Laguna District of Valencia County.

The Recapture Member is a gray mudstone unit, 200 feet thick, with minor thin-bedded fine-grained sandstone. The Westwater Canyon Member is a reddish brown to gray, medium-grained arkosic sandstone, 300 feet in thickness in the area of the San Luis GRA. It is composed of many lenticular and cross-bedded sand channels which are commonly scoured at their bases. The Westwater Canyon Member is the host for most of the uranium ore reserves of the Grants Uranium Region of northwestern New Mexico. In southwest San Juan Basin the Brushy Basin Member consists of a lower mudstone unit, 250 feet thick, and the upper previously mentioned Jackpile sandstone unit, up to 150 feet in thickness. The Jackpile sandstone pinches out along both the southern edge and northern edges of the San Luis GRA (Santos, 1975).

Cretaceous

Cropping out in the San Luis GRA are the Dakota Sandstone and Mancos Shale; the Mesaverde Group which is comprised of the Gallup Sandstone, Crevasse Canyon Formation, Point Lookout Sandstone, Menefee Formation and Cliff House Sandstone; and the Lewis Shale. All are Late Cretaceous in age and were deposited during several southwestward transgressions and northeastward regressions (Hilpert, 1969). As a result, in most of the GRA the Mancos Shale interfingers with the Gallup Sandstone, Crevasse Canyon Formation and the Hosta Tongue of the Point Lookout Sandstone, all lower

formations of the Mesaverde Group. In the very northernmost part of the GRA the Gallup, Crevasse Canyon and Hosta are missing and the contact between the Mancos Shale and the overlying Point Lookout Sandstone is gradational.

Dakota Sandstone

A regional unconformity separates the Dakota Sandstone from the underlying Brushy Basin Member of the Morrison Formation. The Dakota Sandstone is a name that has been used in different ways in many different areas in New Mexico and adjacent states. The Dakota rocks have been called Dakota Group, Dakota Formation, and Dakota Sandstone. The Dakota Sandstone, as used in this report, is a unit of fluvial and near-shore marine sandstones, located stratigraphically above the Morrison Formation and below the Mancos Shale. Minor coal and coalified debris can be found near the base of the Dakota at many localities, but no significant coal beds in the Dakota have been reported to occur in southeastern San Juan Basin. The Dakota Sandstone in the San Luis GRA is about 150 feet thick, gray to brown in color, and varies from fine-grained sand to conglomerate with minor interbeds of mudstone. The top of the Dakota Sandstone is gradational into the overlying Mancos Shale.

Mancos Shale

Conformably overlying the Dakota Sandstone are the gray marine shale and lesser fine-grained sandstone of the Mancos Shale (Hilpert, 1969). The lower Mancos includes rocks of Gallup Sandstone age. The Mulatto Tongue or middle Mancos is of similar age to part of the Crevasse Canyon Formation. The upper Mancos is also called the Satan Tongue. The Hosta Tongue, grouped with the Point Lookout Sandstone, also interfingers with Mancos sediments.

Gallup Sandstone

The Gallup Sandstone is the basal formation of the Mesaverde Group and in the area of the San Luis GRA is up to 200 feet thick. The unit is highly variable in thickness and is absent in roughly the north half of the GRA (fig. 2). The unit is light gray, medium- to coarse-grained, cross-bedded sandstone (Hilpert, 1969). Coal is present locally in the Gallup but has not been reported in the southeastern San Juan Basin.

Crevasse Canyon Formation

In the San Luis GRA, the Crevasse Canyon beds are the predominantly shale section above the Gallup Sandstone and below the Hosta Sandstone Tongue of the Point Lookout Sandstone. The interval is about 600 feet thick and contains the Dilco Coal Member near its base and the Gibson Coal Member in the upper part. The Dilco coals are thin or absent in the San Luis GRA, but coals of the Gibson Coal Member have been mined in the Rio Puerco coal fields in the southeast corner of the GRA. The Rio Puerco coal field is in a small outlier of Mesaverde Group that is separated from the main part of the San Juan Basin.

Point Lookout Sandstone

The Point Lookout Sandstone (200 feet thick), is a fine- to medium-grained sand unit of regressive marine origin. Its lower contact is gradational with the upper Mancos Shale (Satan Tongue). The Hosta Tongue of the Point Lookout Sandstone is separated from the rest of the Point Lookout by up to 500 feet of upper Mancos Shale in much of the San Luis GRA. North of 35° 45' N in the very northernmost part of the GRA, the Hosta Tongue is absent and the Mancos Shale occupies the entire interval from the top of the Dakota Sandstone to the base of the main body of the Point Lookout

Sandstone. This is a stratigraphic interval of about 2000 feet in the San Luis GRA.

Menefee Formation

The Menefee Formation contains the most important coal resources of the San Luis GRA. The formation has been divided into three members, based mainly on the presence or absence of coal (Tabet and Frost, 1979). The lower coal-bearing member is the Cleary Member, which is 200 to 300 feet thick. The unit is of continental origin and consists of mudstones, coal, and sandstones. The middle member of the Menefee Formation is the Allison Member, which is barren of coal and has much more sand than the lower or upper members of the Menefee. The Allison Member is 400 to 500 feet thick and is mainly channel sandstone and mudstone. The upper member of the Menefee is unnamed. It is up to 650 feet thick in the San Luis GRA. The lithology is similar to that of the Cleary Member. The thicker coal beds are in the upper part of the upper member. The total thickness of the Menefee Formation in the San Luis GRA is 1200 to 1500 feet.

Cliff House Sandstone

The Cliff House Sandstone is the uppermost formation in the Mesaverde Group. It conformably overlies the Menefee Formation and in the San Luis GRA it consists of up to 200 feet of fine-grained marine sandstone. The La Ventana Tongue of the Cliff House Sandstone is stratigraphically lower than the main body of the Cliff House and in some places occurs within the upper part of the Menefee Formation. Along the extreme north edge of the San Luis GRA, the La Ventana Tongue occupies roughly the same time-stratigraphic position as the main body of Cliff House Sandstone does in the northwest part of the GRA.

Lewis Shale

The youngest Cretaceous formation found in the San Luis GRA is the Lewis Shale, which is a silty, gray, marine shale conformably overlying the Cliff House Sandstone. The Lewis Shale has a maximum thickness of about 1500 feet (Hilpert, 1969) but less than that is present in the San Luis GRA.

Tertiary Igneous Rocks

Both intrusive and extrusive igneous rocks of Tertiary age are found in the San Luis GRA. The intrusive rocks are isolated basaltic stocks and volcanic plugs such as Cabezon Peak, Cerro Cochino and Cerro Cuate. The extrusive rocks are basaltic flows that form the resistant cappings of Mesa Prieta and Mesa Chivato.

Tertiary to Quaternary

Included are fluvial sediments, pediments, and terrace deposits that form a thin cover over the older rocks in some areas of the eastern part of the San Luis GRA. These sediments do not crop out in any of the WSAs.

Quaternary

Alluvium

Alluvial sediments of Quaternary age are found along the major drainages such as Río Salado and the Jemez River. Most of the small surficial deposits are not shown on Figure 2. These deposits are mainly important only as potential sources of sand and gravel.

Basaltic Talus

Most of the basaltic plugs have talus accumulations around their flanks and are capped by scoriaceous basalt (for example, Cabezon Peak), therefore some resources of this material exist within the WSAs (Brown, 1969).

Structural Geology and Tectonics

The dominant structural and tectonic features of the San Luis GRA are the Nacimiento uplift on the east edge of the area, the northwest-sloping areas on the edge of the San Juan Basin, and the isolated volcanic plugs and flows of Mesa Chivato and Mesa Prieto. The southern part of the San Juan Basin is commonly called the Chaco Slope, and the GRA is at the eastern end of the Chaco Slope. Minor northeast-trending structures in the south part of the area include the Mt. Taylor syncline, Santa Rosa anticline, and Puerco platform. The Nacimiento fault, on the west edge of the Nacimiento Mountains, is a high-angle reverse fault at least 30 miles long and with at least 10,000 feet of displacement. The Puerco fault zone also extends across the GRA in a roughly N-S direction. This major zone of faulting is a series of mostly normal faults striking N 20 degrees E.

Paleontological Documentation

The sedimentary rocks exposed in the San Luis GRA contain fossils representative of the geologic periods from Mississippian through Quaternary. The Mississippian fossil assemblage in this area has been important in establishing a record of Mississippian marine transgression in this part of New Mexico. This invertebrate marine assemblage is found in the Arroyo Penasco Formation, which is exposed only in a few small erosional remnants in the Nacimiento Mountains (in T22 and 23N-R1E) and north of this area in the San Pedro Mountains (in T22 and 23N-R1E and 1W). The type locality of the Arroyo Penasco Formation is in section 5-T16N-R1E, where about 150 feet of limestone and chert was described by Fitzsimmons and others (1956). The fossil assemblage includes foraminifera, corals, bryozoans, crinoids, brachiopods, mollusks, and ostracods. The age was placed by Fitzsimmons, et al. (1956), as Meramecian (Middle Mississippian) and has later been

designated variously as Meramecian or Osagean-Meramecian. Evidence of mid-Mississippian marine transgression in northern New Mexico has been important in reconstructing the geological history of the area. On many published maps, a limestone unit mapped as the "lower limestone member of the Sandia Formation (Pennsylvanian)" probably is really Arroyo Penasco Formation of Mississippian age.

Other fossiliferous parts of the sedimentary section are found in most of the major units, ranging in age from the Pennsylvanian Madera Limestone to the Tertiary/Quaternary volcanoclastics. One particularly noteworthy unit is the Agua Zarca member of the Chinle Formation. In this unit, fossil logs and associated carbonaceous debris have been found to be important reductants in localizing the copper-silver ores along the Nacimiento front. The Morrison Formation is known in many areas to contain well-preserved dinosaur fossils, but to the writer's knowledge none have been found within the San Luis GRA.

Geologic History and Paleogeographic Development

The early Precambrian in this area has not been extensively studied and is poorly known. The oldest rock is Precambrian granitic gneiss, with schist xenoliths, intruded by granite and quartz monzonite. These rocks have been age-dated as 1.5 to 1.8 billion years B.P. (Condie, 1981; Brookins, 1974). Any later Precambrian sediments that may have been deposited in this area were removed by erosion; no record of them has been found. The area was also emergent during Cambrian through Devonian time but the area was probably tectonically inactive during these periods. In early Mississippian time there was a shallow marine transgression, probably from the northwest or southeast or both. The area was a stable marine shelf during Osage and Meramec time, as evidenced by the fossiliferous and cherty limestones now preserved as the Arroyo Penasco Formation. Most of these carbonates were removed by erosion before the beginning of the Pennsylvanian Period.

From early Pennsylvanian through Jurassic time, the area was alternately subject to minor erosional and depositional cycles resulting in the preservation of about 4300 feet of mixed marine and continental sediments of Pennsylvanian through Jurassic ages. The earliest of these episodes that left a sedimentary record was in the Middle Pennsylvanian (probably Atokan) and left preserved a 100 feet of fluviatile sediments, mostly dark sandy shales (Sandia Formation) overlain by 700 feet of mostly carbonate sediments of Desmoinesian and Missourian age (Madera Limestone).

During the Permian Period, this area was alternately subjected to marginal marine clastic deposition, erosion and dessication, and fluviatile sedimentation. The resulting sedimentary units are the Permian redbeds of the Abo, Yeso, and Glorieta formations (total thickness of 1000 feet). These are favorable host rocks for deposition and preservation of copper-silver and uranium deposits.

No record remains of the Early and Middle Triassic in this area, but the late Triassic left an important record of 1000 to 2000 feet of alternating fluviatile clastics and shallow marine shales, the Chinle Formation. These units are important as host rocks for copper-silver ore in this area and for uranium ore in other areas (Shinarump conglomerate of the Chinle; Four Corners area).

During the Early and Middle Jurassic the San Luis area was emergent. In the Late Jurassic, subsidence and marine fluctuations resulted in a sequence of marginal marine fluvial and continental units. From oldest to youngest, these are the Entrada Sandstone, Todilto Limestone, Todilto evaporite, Summerville clastics, and the Morrison Formation consisting of two fluvial/continental members (Recapture and Westwater Canyon) and an upper shale member (Brushy Basin) indicating more marine conditions. At the end of Brushy Basin time, an important marginal marine fluvial channel sand was

deposited which is at least approximately equivalent to the Jackpile sandstone of local economic usage in the Laguna uranium district. This unit is preserved in the San Luis GRA and is very similar to the Jackpile sandstone, although it may have had a different source area (Santos, 1975).

The earliest Cretaceous record is missing in the San Luis area, but the remainder of the Cretaceous Period resulted in a thick sequence of sediments showing, in general, a series of transitions between marine and continental deposition. The marine deposition produced important oil and gas reservoirs such as in the Dakota Sandstone, Mancos Shale, Gallup Sandstone, Point Lookout Sandstone (including Hosta Tongue), and the Cliff House Sandstone. The episodes of continental deposition during Late Cretaceous time produced the important coal resources of the Mesaverde Group.

The area was slightly emergent around the end of the Cretaceous Period. The Cretaceous sediments younger than the Lewis Shale have been removed by erosion. During early Tertiary time the area probably received some sedimentary deposits but none of them are preserved within the area of the San Luis GRA. During the Laramide Orogeny of Late Cretaceous or Early Tertiary time the Nacimiento Mountains were uplifted. The Nacimiento thrust fault, and most of the presently existing structural features, probably also formed during the Laramide Orogeny. The normal faults of the Puerco fault zone are somewhat younger, probably Paleocene in age, because they offset the thrust faults (Hilpert, 1969, pg. 30).

The volcanic activity in this part of the San Juan Basin started in Late Tertiary time, probably about 20 million years ago, and continued possibly into the Quaternary period. Late Tertiary and Quaternary continental sediments have been deposited in the areas along the flanks of faults and highland areas, and the area has been partially dissected by erosion during the latest Tertiary and Quaternary time.

ENERGY AND MINERAL RESOURCES

Known Mineral Deposits with Recorded Production

The principal known deposits within the San Luis GRA are petroleum, coal, gypsum, uranium, humates, sand and gravel, and limestone. In addition, there are important resources of copper and silver in sedimentary rocks a few miles north of the GRA. The deposits in active production in 1982 are petroleum, coal, gypsum, humates, and sand and gravel. These are listed below and are shown in Fig. 2.

Gypsum

1. White Mesa Mine, Pomeroy Inc.
Location: Sec. 14, T15N-R1E
Status: Active
Producing Formation: Todilto
2. Blue Sky
Location: Sec. 16, T15N-R1E
Status: Active
Producing Formation: Todilto

Gypsum reserves and resources in the Todilto Formation are extensive in this area and extend along the outcrop to the west and north. The areas that have been developed are the areas of gentler dips and less overburden.

Coal

3. Arroyo #1 Mine
Location: Sec. 16, T17N-R2W
Status: Active
Producing Formation: Menefee
4. Tonepak Mine
Location: Sec. 23, 26, 27, T18N-R2W
Status: Inactive
Producing Formation: Menefee

The coals of the Menefee Formation are present under roughly the western half of the GRA. The main coal-bearing zones are in a NE-SW trending zone from northeast of the village of San Luis to the northeast edge of Mesa Chivato. Another small area of known coal is in the southeast corner of the GRA (Rio Puerco coal field).

Oil and Gas

5. Name of Field: San Luis (oil)
Location: Sec. 21, 28, 33, T18N-R3W
Year of discovery: 1959
Producing Horizon: Mesaverde
Depth (feet): 200-1000
Type of trap: stratigraphic
6. Name of Field: Torreon (gas)
Location: Sec. 22, 27, T18N-R4
Year of discovery: 1953
Producing Horizon: Mesaverde
Depth (feet): 1000-1100
Type of trap: stratigraphic

Uranium

7. Collins-Goodner
Location: Sec. 25, 36, T17N-R1W
Status: inactive
Producing Formation: Morrison (Westwater Canyon)

This small operation had a reported production of 395 tons of ore averaging 0.13% U_3O_8 in 1957-1959 (Chenoweth, 1974).

Humates

8. Location: NW 1/4 of Sec. 8, T14N-R1E
Status: Active
Producing Formation: Mesaverde Group
9. Location: NE 1/4 of Sec. 3, T14N-R1E
Status: Permitted, but not working (August, 1982)
Producing Formation: Mesaverde Group

Humates are relatively common materials. Other deposits undoubtedly exist in the outcrop areas of the Mesaverde Group. Development is dependent on overburden and access to markets.

Sand and Gravel

10. Location: Sec. 33, T15N-R1E
Status: active
Producing Formation: alluvium(?)

Many other small deposits of sand and gravel undoubtedly exist in the GRA.

Gas Storage Area at Canada de las Milpas

An unusual geologic resource that exists in the San Luis GRA is the underground storage for natural gas at Canada de las Milpas, west of White Mesa (T15N-R1E, see fig. 2). This area is advantageously located for such a facility, being between the major gas fields of the San Juan Basin and the population centers of the Rio Grande Valley. Gas is fed into an anticlinal reservoir in porous sandstone during periods of low demand and fed into the pipeline during times of peak demand. There may be other nearby structures suitable for this use, such as at Cabezón anticline (east of Cabezón Peak).

Known Prospects and Occurrences with No Recorded Production

Coal

The San Luis GRA is located on the east edge of the major coal fields of the San Juan Basin. The major coals in the GRA are subbituminous B or C in rank and are in the Menefee Formation of the Mesaverde Group. The coal seams are lenticular and irregular in nature. At most places they are from one to three feet thick but in a few places seams up to nine or ten feet thick have been found. Also, there are thin and discontinuous coals, of lesser importance commercially, in the Dakota, Gallup, Crevasse Canyon, and Cliff House formations. At the active coal-mining operation in the Menefee on State land in section 16 of T17N-R2W (Arroyo #1 Mine), the seams are up to three feet thick and are dipping gently to the northwest. Several seams are exposed in the shallow open pit.

In Township 19N and Range 1 W, just north of the San Luis GRA, a Menefee coal seam, locally called the Padilla seam, about 12 feet thick, is exposed and has been worked in a small way. The seam dips westerly at 10-12 degrees.

Some of the Mesaverde coals under the volcanics of Mesa Chivato probably have been partially metamorphosed to the higher rank by the heat from the

volcanics.

Copper-Silver

Copper-silver deposits in sedimentary rocks are known to occur on the east and west flanks of the Nacimiento Mountains in a north-south zone at least 32 miles long (see figure 3). The host rocks are the Triassic Agua Zarca Sandstone Member of the Chinle Formation, Permian Abo Sandstone, and the Pennsylvanian Madera Limestone. The primary source of the copper and silver probably was the Precambrian granite and gneiss of the Nacimiento Mountains. Further, the metal was probably not uniformly distributed in the Precambrian rocks but rather was localized in specific and limited areas. Systematic sampling and mapping in the Precambrian outcrops could be expected to outline the most favorable areas for prospecting in the flanking sediments. In the areas where the favorable source rocks are associated with good trapping mechanisms, target areas for discovery of new ore deposits can be outlined. The copper and silver are closely associated and can be considered as one type of deposit.

11. Location: Sec. 19, T18N-R1E
Host Rock: Abo Formation
References: # 18 of Kaufman, 1972
12. Location: Sec. 30, T18N-R1E
Host Rock: Madera Formation
References: # 19 of Kaufman, 1972

Townships and ranges are projected because these are on the Jemez Indian Reservation which is unsurveyed by the Public Land Survey. There are many other prospects extending to the north, but not on the San Luis GRA.

Uranium

The major uranium producing areas of the Grants region lie to the south and west of the San Luis GRA. The closest of the major deposits (in the north part of the Laguna District of the Grants Uranium Region) are only

about six miles south of the GRA boundary and only about 20 miles south of the Chamisa and Ojito WSAs. Similar host rocks (in the Westwater Canyon and Brushy Basin Members of the Jurassic Morrison Formation) are found under most of the GRA and under all of the subject WSAs. Major uranium deposits have not been found within this GRA, although considerable exploration drilling has been done. Smaller deposits and occurrences have been found within this GRA, and some have been mined. The most important of these deposits are in the White Mesa area and north along the Nacimiento Mountain front to the La Ventana area. An assessment by the U.S.G.S. of the Jurassic formations present in this area found the lithology and the geologic setting to be similar to those of the Grants region (Santos, 1975). Noting minor differences between this area and the Grants region, Santos concluded that further exploration in this area was warranted.

In the U.S. Department of Energy evaluation of the Albuquerque one degree by two degree quadrangle (Green, et al., 1980), the Brushy Basin and Westwater Canyon Members of the Morrison Formation were rated as favorable for uranium over the entire area covered by the six WSAs in the San Luis GRA. The maximum drilling depth to the base of the Westwater Canyon within the San Luis GRA is estimated as 3,400 feet. This is not beyond the economic limit of current uranium mining. Ore in the Westwater Canyon Member is known to occur at least to 4,000 feet in the Mt. Taylor deposit about 10 miles southwest of the GRA. Also, uranium mineralization in the Westwater Canyon has been found at depth greater than 4,000 feet in the East Chaco Canyon drilling project of the U.S. Department of Energy (Hicks, et al., 1980).

Uranium Prospects (Production Unknown)

13. Deer Creek
Location: Sec. 35, T18N-R1E
Host rock formation: shale in Abo Formation
Reference: Hilpert, 1969
14. Unknown
Location: Sec. 13, T18N-R1W
Host rock formation: shale in Dakota Sandstone
Reference: Hilpert, 1969
15. Burcar
Location: Sec. 12, T17N-R1W
Host rock formation: Dakota Sandstone(?)
Reference: Hilpert, 1969
16. Goodner Seville
Location: Sec. 11, T17N-R1W
Host rock formation: Brushy Basin Member, Morrison Formation
Reference: USBM, 1982, MILS, sequence no. 0350430178
17. Unknown
Location: Sec. 23, T17N-R1W
Host rock formation: Brushy Basin Member, Morrison Formation
Reference: USBM, 1982, MILS, sequence no. 0350430443
18. Anomaly #6
Location: Sec. 18, T17N-R1W
Host rock formation: Tuffaceous Pumice
Reference: Green et al., 1980
19. Unknown
Location: Sec. 26, T17N-R1W
Host rock formation: Dakota Sandstone(?)
Reference: USBM, 1982, MILS, sequence no. 0350430442
20. Collier
Location: Sec. 25, T17N-R1W
Host rock formation: Sandstone in Brushy Basin Member, Morrison Formation
Reference: Hilpert, 1969
21. Section 36
Location: Sec. 36, T17N-R1W
Host rock formation: Westwater Canyon Member, Morrison Formation
Reference: Hilpert, 1969
22. Anomaly #2
Location: Sec. 6, T16N-R1E
Host rock formation: Granite
Reference: Green et al., 1980

23. Unknown
Location: Sec. 7, T16N-R2E
Host rock formation: Madera Limestone(?)
Reference: Green et al., 1980
24. Unknown
Location: Sec. 12, 16N-R1E
Host rock formation: Madera Limestone(?)
Reference: Green et al., 1980
25. Hovey Ranch
Location: Sec. 13, T17N-R4W
Host rock formation: Point Lookout Sandstone
Reference: Green et al., 1980
26. Lone Wolf
Location: Sec. 11, T15N-R1W
Host rock formation: Morrison Formation
Reference: USBM, 1982, MILS, sequence no. 0350430233
27. Rattlesnake
Location: Sec. 14, T15N-R1W
Host rock formation: Morrison Formation
Reference: USBM, 1982, MILS, sequence no. 0350430327
28. Yellow Cliffs
Location: Sec. 21, T15N-R1W
Host rock formation: Morrison Formation
Reference: USBM, 1982, MILS, sequence no. 0350430457
29. Morris-Peters #1
Location: Sec. 17, T15N-R1E
Host rock formation: Brushy Basin Member, Morrison Formation
Reference: Hilpert, 1969
30. Morris-Peters #3
Location: Sec. 20, T15N-R1E
Host rock formation: Brushy Basin Member, Morrison Formation
Reference: Hilpert, 1969
31. Morris-Peters #2
Location: Sec. 21, T15N-R1E
Host rock formation: Brushy Basin Member, Morrison Formation
Reference: Hilpert, 1969
32. Lone Star
Location: Sec. 27, T15N-R1E
Host rock formation: Mancos Shale
Reference: Green et al., 1980
33. Unknown
Location: Sec. 26, T15N-R1E
Host rock formation: Shale in Dakota Sandstone
Reference: Green et al., 1980

34. Unknown

Location: Sec. 31, T15N-R1E

Host rock formation: Dakota Sandstone

Reference: Green et al., 1980

Humates

In recent years there has been significant mining of low-grade, impure and weathered coals for use as a soil conditioner. These materials contain organic acids including humic acids and are called humates. The most desirable material for this purpose is a low-grade, silty coal or carbonaceous shale, containing some bentonite, elemental sulfur, and sometimes gypsum. The material improves the tilth of many soils by providing organic content and lowers the pH of alkali soils.

The two currently active operations (July, 1982) are in Mesaverde coals. Other active operations are a few miles north of the San Luis GRA. Since the humates are relatively common materials, it is likely that humate operations could be developed at many other locations in the GRA if they were close enough to transportation and markets. In general the most likely places for these deposits are in the outcrop areas of the Menefee Formation (mapped as Mesaverde undivided in some areas). Some of the thinner and impure coals in the Dakota, Gallup, Crevasse Canyon, or Cliff House might also support humate operations. There are no specific prospects to cite, but many prospective areas probably exist.

Oil and Gas

The San Luis GRA is located in the southeast part of the San Juan Basin, a prolific oil and gas producer from Mesozoic and Paleozoic reservoirs. Petroleum source rocks such as the Mancos Shale and the Todilto Limestone underlie most of the area except the Nacimiento Mountains. Important Cretaceous reservoir rocks include the Point Lookout, Hosta, Gallup, and

Dakota Sandstones. Northwest of the area, the lower Cretaceous Gallup Sandstone produces large amounts of oil and the Dakota Sandstone produces oil in the nearby Hospah and Lone Pine Oil fields. The Entrada Sandstone (Jurassic) produces large quantities of oil from small anticlinal features of very small areal extent not having surface expression, but which can be defined by seismic methods. An example of this is the Media field in T19N-R3W. The (Pennsylvanian) Sandia Formation has had oil shows in wells drilled in the vicinity and offers an additional possibility for oil and gas production. Another important producing formation within the area is the Mancos Shale, which has produced over 14,000,000 barrels of oil from fractured reservoirs in the Puerto Chiquito fields in the eastern part of the San Juan Basin. The Mancos Shale is the subject of drilling during 1982 in T20N-R3W and 4W.

Geothermal

Approximately the eastern half of the San Luis GRA has been classified by the U.S. Geological Survey as prospectively valuable for geothermal resources (Godwin, 1971; De Cicco, et al., 1978). A major area of geothermal power development is about 15 miles northeast of the GRA boundary, at Valles caldera. On the west side of the caldera, about 12 miles from the San Luis GRA, is the experimental Hot Dry Rock geothermal test site operated by the U.S. Department of Energy. However, all the WSAs are west of the Nacimiento fault and so are not in the province of high heat flow near the Valles caldera. Closer to the GRA, but still three miles east of it, there are several hot springs (up to 76 degrees C) near the town of Jemez Springs. However, this is about 9 miles east of the Nacimiento fault and so is not in the same geologic province as are the WSAs west of the fault. There is another area of moderately warm water (up to 50 degrees C) in the San Mateo

fault zone, which is west of the GRA.

Mining Claims, Leases, and Material Sites

There are many claims in the southeast part of the GRA (including White Mesa and the Ojito WSA), in the northeast part along the Nacimiento front, and some in the west-central part in the Empedrado and La Lena WSAs. Also there are oil and gas leases on most of the Ignacio Chavez WSA. Mining claim density of the area is summarized in table 2 and shown in figure 4.

Mineral Deposit Types

There are many types of known and potential mineral deposits in this area. The most important types are:

- a. Oil and gas in the entire area except the Nacimiento Mountains;
- b. copper-silver in the Chinle clastics, Madera carbonates, Abo clastics, and Todilto carbonates;
- c. uranium in the Westwater Canyon and Brushy Basin Members of the Morrison and in the Todilto Limestone;
- d. sub-bituminous coal occurs in the Menefee formation and the Crevasse Canyon Formation;
- e. humates are associated with the Menefee and Crevasse Canyon coals and possibly some other units,
- f. gypsum deposits are associated with the Todilto Formation, which is well known; development is limited mainly by markets, depth of overburden, and the areas of gentler dips.

Mineral Economics

In the San Luis GRA, the development of several commodities of low unit value is dependent mainly on access to markets, overburden, and transportation. These include sand and gravel, humates, and to a degree

TABLE 2: CLAIM DENSITY RECORDS IN THE WILDERNESS STUDY AREAS,
SAN LUIS GRA, ACCORDING TO BLM, NEW MEXICO OFFICE, SANTA FE

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION	CLAIMANT(S)	LATEST ASSMT DATE
16N	2W	18	NW 3	Energy Reserves Grp.	1980
			W2 1	"	"
			SW 5	"	"
		19	NW 4	"	"
			SW 4	"	"
			E2 1	"	"
		30	NW 4	"	"
			SW 4	"	"
			W2 1	"	"
15N	3W	16	SW 1	Yurth W Mesaros Frank J	1979
		17	SE 6	"	"
			W2 4	"	"
			SW 3	"	"
			ALL 1	"	"
			E2 4	"	"
			S2 1	"	"
		18	SE 9	"	"
			SW 4	"	"
			NE 1	"	"
		19	NE 11	"	"
			NW 8	"	"
			N2 1	"	"
			S2 1	"	"
			W2 1	"	"
			E2 4	"	"
			ALL 1	"	"
			SW 3	"	"
			SE 5	"	"
		20	NE 1	"	1980
			NE 5	"	1979
			SW 6	"	"
			NW 3	"	"
			N2 1	"	"
		30	NW 2	"	"
16N	3W	3	NW 4	Sayre Robert M	1980
				Sayre Robert H	"
				Gulf Oil Corp.	"

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION	CLAIMANT(S)	LATEST ASSMT DATE
16N	3W	3	NW 3 W2 3 SW 6	Energy Reserves Grp. " "	1980 " "
		4	NE 3 NW 1 N2 2 SW 8 S2 2 SE 8 NE 4 ALL 1 E2 4 W2 4	Sayre Robert M Sayre Robert H Gulf Oil Corp. Sayre Robert M Sayre Robert H Energy Reserves Grp. " " " " " " "	1980 " " " " " " " " " "
		5	SW 9 S2 2 NE 5 E2 5 W2 4 NW 4 SE 10 ALL 1 N2 1	" " " " " " " " "	" " " " " " " "
		6	SW 6 S2 2 SE 8 E2 4 N2 1 W2 3 ALL 1 NE 4 NW 3	" " " " " " " " "	" " " " " " " "
		7	SW 8 SE 8 E2 2 N2 2 ALL 1 W2 1 SE 1 NE 8 NW 6	Gulf Mineral Resource " Energy Reserves Grp. " " " " " "	1981 " 1980 " " " " "
		9	NE 7 NW 4 E2 1	Coggins Sons, Inc. " "	1981 " "

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION	CLAIMANT(S)	LATEST ASSMT DATE
16N	3W	9	N2 4	Coggins Sons, Inc.	1981
			NW 4	Energy Reserves Grp.	"
			NE 4	"	"
			N2 1	"	"
		10	NW 8	Coggins Sons, Inc.	"
			N2 4	"	"
			NE 4	"	"
			NW 3	Energy Reserves Grp.	1980
		13	NW 2	"	"
			N2 4	"	"
			W2 2	"	"
			ALL 1	"	"
			SW 4	"	"
			SE 10	"	"
			S2 5	"	"
			NE 6	"	"
			E2 2	"	"
		18	NW 8	Gulf Mineral Resource	1981
			NE 8	"	"
			SE 10	"	"
			SW 6	"	"
		19	NW 7	"	"
			NE 9	"	"
			SE 4	"	"
			SE 4	"	"
		24	SE 8	"	"
			NW 3	"	"
			N2 4	"	"
			ALL 1	"	"
			SW 2	"	"
			S2 5	"	"
			W2 2	"	"
			E2 1	"	"
			NE 8	"	"
		25	SW 1	"	"
			ALL 1	"	"
			S2 4	"	"
			NE 8	"	"
			E2 2	"	"
			SE 8	"	"
17N	3W	19	NW 8	UNC Teton Expl. Dr1g.	1981
			SW 8	"	"
			NE 8	"	"

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION		CLAIMANT(S)	LATEST ASSMT DATE
17N	3W	19	SE	8	UNC Teton Expl. Drlg.	1981
			SW	8	"	"
		29	NE	5	Teton Expl. Drlg.	"
			SE	4	"	"
			NW	1	"	"
			NW	10	UNC Teton Expl. Drlg.	"
			SW	8	"	"
		30	NW	10	"	"
			SW	8	"	"
			NE	10	"	"
			SE	8	"	"
		31	NW	10	"	"
			NE	10	"	"
			SE	8	"	"
			SW	8	"	"
		33	SE	7	Sayre Robert M	1980
			SW	1	Sayre Robert H	"
					Gulf Oil Corp.	"
			S2	4	Sayre Robert M	"
			SW	4	Sayre Robert H	"
			W2	1	"	"
			NW	4	"	"
16N	4W	1	SE	8	Energy Reserves Grp.	1980
			S2	1	"	"
			SW	8	"	"
			E2	5	"	"
			ALL	1	"	"
			W2	4	"	"
			NE	4	"	"
			N2	1	"	"
			NW	4	"	"
		3	SE	1	"	"
		4	N2	1	Rocky Mt. Energy Co.	"
		10	SE	1	Energy Reserves Grp.	"
			E2	1	"	"
			NE	2	"	"
		11	SE	5	"	"
			E2	5	"	"
			SW	4	"	"

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION	CLAIMANT(S)	LATEST ASSMT DATE
16N	4W	11	W2 4 N2 2 NE 10 NW 8 S2 1	Energy Reserves Grp. " " " "	1980 " " " "
		12	NE 8 N2 2 NW 8	" " "	" " "
		13	NE 12 NW 8 SE 10 SW 8	Gulf Mineral Resource " " "	1981 " " "
		14	NE 9 NW 8 SE 9 SW 9	" " " "	" " " "
		23	NE 9 NW 9 SW 10 SE 8	" " " "	" " " "
		24	NE 5	"	"
		26	SE 1 NW 1	Sayre Robert M Sayre Robert H	none location date 2-22-77
		28	S2 3 N2 1 SW 2	Rocky Mt. Energy Co. " "	1980 " "
		29	SE 1	"	"
		32	SW 3 E2 2 W2 1 NE 1	" " " "	1981 1980 " "
		33	W2 9 N2 4 S2 5 E2 4 NE 2 NW 3 SW 4 SW 2	" " " " " " " "	" " " " " " " 1981

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION	CLAIMANT(S)	LATEST ASSMT DATE
16N	4W	34	W2 8	Rocky Mt. Energy Co.	1980
			NW 2	"	"
			S2 10	"	"
			SW 1	"	"
			E2 1	"	"
			N2 1	"	"
17N	4W	21	SW 8	UNC Teton Expl. Drlg.	1981
			NE 10	"	"
			SE 8	"	"
		22	SE 4	"	"
		23	SW 4	"	"
			SE 8	"	"
		25	NW 10	"	"
			NE 10	"	"
			SE 8	"	"
			SW 8	"	"
		26	NW 5	"	"
			NE 10	"	"
			SE 8	"	"
		27	NW 8	"	"
			SW 10	"	"
			SE 4	"	"
			NE 5	"	"
		28	NW 10	"	"
			SW 8	"	"
			NE 10	"	"
			SE 8	"	"
		29	SE 10	"	"
			SW 10	"	"
		33	NW 8	"	"
			SW 10	"	"
			NE 8	"	"
			SE 10	"	"
		34	SE 5	"	"
		35	NE 12	"	"
			NW 4	"	"
			SW 5	"	"
			SE 15	"	"

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION	CLAIMANT(S)	LATEST ASSMT DATE
16N	5W	16	SE 10 SW 5	Phillips Uranium "	none location date 5-5-77
		21	NE 12 NW 5 SE 8 SW 5	" " " "	" " " "
		22	NE 9 NW 10 SE 10 SW 11	" " " "	" " " "
		23	NE 2 NW 4 NE 8 NW 6 SE 10 SW 10	" " " " " "	location date 5-4-77 5-5-77 " " "
		24	NE 10 NW 10 SE 10 SW 10	" " " "	" " " "
		25	NW 8 NE 8 SW 4 SE 4 E2 2 W2 2	" " " " " "	" " " " " "
		26	NW 7 NE 8 SE 5 SW 4 E2 2 W2 1	" " " " " "	" " " " " "
		27	NW 9 NE 10 SW 4 SE 3 W2 3 E2 2	" " " " " "	" " " " " "
		28	NW 4 SE 6 W2 1	" " "	" " "

TOWNSHIP	RANGE	SECTION	CLAIMS FOR EACH SECTION	CLAIMANT(S)	LATEST ASSMT DATE
16N	5W	28	E2 2 SW 2 NE 4	" " "	location date 5-5-77 "

gypsum and coal. The only active sand and gravel operations are near the roads and where the market is shortest to the population centers (and therefore the markets) such as Albuquerque and the Rio Grande Valley. The situation is similar in the case of the humates, which occur in the Mesaverde units.

Gypsum of good quality occurs along most of the outcrops of the Todilto Formation, and extends westerly into the subsurface (as the unhydrated equivalent, anhydrite). Gypsum deposits have been developed at White Mesa because the Todilto gypsum beds in that area are near the surface and relatively flat-lying, plus the access is good to Highway 44. Future development will continue along the outcrop into areas of steeper dip and more difficult access, and possibly into the subsurface.

Subbituminous coal development will likewise proceed into the areas of poorer access, and be limited by the variations in quality of the San Juan Basin coals and the (similar) Rio Puerco coals.

The copper-silver and uranium deposits involve ores of high unit value, so they are not so dependent on ease of access. Future development of these deposits will depend on the world metal prices and on the development of geological concepts for discovery of new ore bodies.

Strategic and Critical Minerals and Metals

From the list of strategic and critical minerals and metals provided by the U.S. Bureau of Land Management for this project, only copper and silver are known to occur within the San Luis GRA. There are two minor occurrences of copper-silver in sedimentary rocks along the Nacimiento fault in the northeast part of the GRA. There are many more occurrences and some past producing mines within a few miles north from the GRA. No occurrences of copper or silver are known within the six WSAs but the favorable rocks are

present under all of them. The favorability for copper-silver deposits is rated as 3-B in the Ojito WSA and 2-B in the other five WSAs, the difference being based on the depth to the favorable Triassic host rocks.

LAND CLASSIFICATION

The classification system used in this report is shown as follows (after BLM specification for this project):

Classification Scheme

1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.
2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.
3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.
4. The geologic environment, the inferred geological processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Level of Confidence Scheme

- A. The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.
- B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

- C. The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.
- D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

Locatable Resources

Metallic

The known occurrences of copper and silver are mainly along the Nacimiento fault. In the same area and in the same geologic setting there is also a potential for gold, molybdenum, and other metals. The favorable host rocks are present under all the WSAs at feasible drilling depths. Considering geologic environments and information available, the land classification with regard to metallic deposits is 4-C (fig. 5, sub-area 1).

Uranium and Thorium

The known occurrences of uranium are in the same areas as the copper-silver, plus occurrences in the Ojito area (T15N-R1W) and a reported occurrence between the Empedrado and La Lena WSAs (in sec. 34, T17N-R4W). Major uranium deposits in the region in the same formations, plus other favorable environments make this area of high favorability for uranium with a high level of confidence class 4-D (fig. 6, sub-area 1).

Nonmetallics

The active gypsum mining operations, plus extensive additional reserves and resources, make this a favorable area for further gypsum development. There are also known resources of limestone and possibly some locatable clays of high unit value. The land classification is 4-D (fig. 7, sub-area 3).



FIG. 7 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR GYPSUM RESOURCES OF THE SAN LUIS AREA, NEW MEXICO.

Leasable Resources

Oil and Gas

There are producing oil fields within the GRA, plus shows and exploratory tests (4-D, fig. 8, sub-area 1). Favorable reservoirs and source beds are present under all the area except the extreme eastern edge. The past drilling density is about eight tests per township. The land classification is 3-C (fig. 8, sub-area 2).

Oil and gas assessment in each individual WSA considers also the following comments and considerations:

Ignacio Chavez WSA

Part of this area is covered by a veneer of volcanic rocks. An anticlinal nose extends toward the northwest portion of the area indicating the possibility of an anticlinal closure within the Ignacio Chavez WSA. Reservoirs including Mesaverde, Gallup, Dakota, Entrada and possibly Sandia Sandstones indicate fair to good possibility of hydrocarbon accumulations within the area.

Empedrado WSA

The Chico anticline, a major structure within the general area, appears to continue eastward into the Empedrado area. Since Mesaverde, Gallup, Dakota and Entrada Sandstones are at drillable depths within the Empedrado area, the possibilities of encountering hydrocarbon are fair to good.

La Lena WSA

This area includes a general homoclinal zone within the area. Consequently only stratigraphic traps would be envisioned for oil and gas accumulations. The Gallup Sandstone and the Entrada Sandstone might be the most likely resevoirs, and more detailed geophysical studies are required to

assess this possibility.

Ojito WSA

This area may include part of the Cabezon anticline, a possible oil trap in which the Cretaceous Gallup and Dakota sands; the Jurassic Entrada and the Pennsylvanian Sandia Formation occur at drillable depths.

Cabezon WSA

The Cabezon WSA is located within a major synclinal zone within the area; therefore the possibilities of hydrocarbon production are rather poor in this area.

Chamisa WSA

The axis of the Guadalupe anticline crosses this area in a north-south direction, the structure plunging toward the north. The Dakota and Entrada sandstones are the most promising reservoirs for oil and gas accumulations. The Pennsylvanian Sandia Sandstone would be an additional reservoir if present. The possibilities of oil and gas accumulation are fair within this area.

Geothermal

Known resources of high-temperature geothermal energy are east of the GRA (Fenton Hill and Valle Grande) and low-temperature resources are known on the west edge of the GRA (San Mateo fault zone). Within the GRA the favorability is lower.

Sodium and Potassium

There are no resources of these commodities known in the GRA, but evaporites do exist (gypsum and anhydrite in the Todilito Formation) so there is a possibility of bedded sodium and potassium minerals.

Coal

There are known resources of mineable subbituminous coal in a large part of the GRA and one currently active operation (July, 1982; 4-D, sub-area 1, fig. 9). Development is limited by demand, mining cost, and access. The land classification is 4-C (fig. 9, sub-area 2).

Saleable Resources

Sand and Gravel

There is one active operation in the GRA and others that could be developed if needed.

Clay (common varieties)

Clay has been little investigated in this area, because of remoteness from markets and the abundance of reserves elsewhere.

Humates

Humates are being actively mined in the San Luis GRA and in nearby areas. This is an example of development of a "new" resource and additional development can be expected.

Petrified Wood

This resource has been little investigated in this area, but some can be expected in the Morrison, Agua Zarca and other units.

Classification of Wilderness Study Areas

Copper-Silver

Ojito WSA (3-B)

In the Ojito WSA the favorable host rocks for copper-silver deposits (Agua Zarca Member of the Triassic Chinle Formation) are present at depths from 1200 feet to 3000 feet. These are not prohibitive depths for



commodities of high unit value, so the Ojito WSA is classified as moderately favorable for copper-silver deposits (fig. 5, sub-area 2).

Cabezon, La Lena, Empedrado, Chamisa, and Ignacio Chavez WSAs (2-B)

These five WSAs are all classified the same for copper-silver potential (fig. 5, sub-area 3). The favorable Triassic host rocks are present, but at depths greater than 3000 feet.

Uranium

Ojito WSA

Sub-area 1 (4-D, fig. 6). This is the part of the Ojito WSA where the favorable Members of the Morrison Formation (Brushy Basin and Westwater Canyon Members) are present in outcrop or in the shallow subsurface. The depth to the top of the Morrison Formation (Brushy Basin Member) is estimated to be 600 feet at the deepest point, the northwest corner of the WSA. The outcrop area of the basal member of the Morrison, the Recapture Member, does not affect the classification because the Recapture Member does not have favorable lithology and is not known to host uranium deposits in the southeastern San Juan Basin.

Sub-area 2 (3-C, fig. 6). This is the part of the Ojito WSA that is not underlain by the Brushy Basin or Westwater Canyon Members of the Morrison Formation. It is rated as moderately favorable because there are uranium occurrences and favorable lithologies in the underlying Jurassic, Triassic, Permian, and Pennsylvanian formations.

Cabezon WSA

Sub-area 3 (3-B, fig. 6) The entire area of the Cabezon WSA is classified as moderately favorable for uranium. The most favorable host

rocks are in the Brushy Basin and Westwater Canyon Members of the Morrison Formation and occur at depths from 1000 feet to 2000 feet. The small igneous stock at Cabezon Peak is less favorable but is not shown separately on the classification map at the 1:250,000 scale. In any case the stock is probably not vertical, so a less favorable map area cannot be outlined. The heat from the intrusion may have remobilized uranium and resulted in emplacement of ore around the periphery of the stock.

La Lena WSA

Sub-area 3 (3-B, fig. 6) This entire WSA is classified as moderately favorable for uranium. The most favorable host rocks are the same as in the Cabezone WSA and occur at roughly 2000 to 3000 feet. Other host rocks, both shallower and deeper, are also prospective but less so. The known uranium prospect in the Point Lookout Sandstone (Sec. 34, T17N-R4W) is not particularly significant.

Empedrado WSA

Sub-area 3 (3-B, fig. 6) Comments are the same as for the La Lena WSA.

Chamisa WSA

Sub-area 3 (3-B, fig. 6) Comments are the same as for the La Lena WSA except that the depth to the most favorable host rocks is from 600 feet to 3000 (2850) feet.

Ignacio Chavez WSA

Sub-area 3 (3-B, fig. 6) Comments are the same as for the La Lena WSA except that the depth to the most favorable host rocks is from 1900 feet to 3000 feet.

Gypsum and Anhydrite

Ojito WSA

Sub-area 1 (4-C, fig.7). The gypsum and anhydrite resources of the San Luis GRA occur in the Todilto Formation of Jurassic age. This sub-area of the Ojito WSA is the part where the known gypsum unit is present at the surface or with an overburden depth of less than 200 feet.

Sub-area 2 (2-A, fig. 7). In this sub-area the gypsum or anydrite is present at a depth of more than 200 feet. Since gypsum is a commodity of low unit value, the favorability is assessed as low in this sub-area because of the abundant resources of gypsum that exist in more accessible adjacent areas with less than 200 feet of overburden.

Cabezon, La Lena, Empedrado, Chamisa, and Ignacio Chavez WSAs

Sub-area 2 (2-A, fig. 7). In all these WSAs the gypsum unit (presumably as the dehydrated form, anhydrite) is at depths greater than 2000 feet. There is direct evidence that the resource is present; the low favorability reflects the fact that the resource is not likely to be developed under current or reasonably anticipated conditions.

Oil and Gas

Ojito WSA

Sub-area 3 (2-C, fig. 8). These are known petroleum source rocks, resevoir rocks, and possible anticlinal structures in the area of the Ojito WSA; but the WSA is so close to the Nacimiento Mountain front that any anticlinal structures may have been flushed by fresh water.

Cabezon WSA

Sub-area 3 (2-C, fig. 8). The Cabezon WSA has about the same favorability as the Ojito WSA. The intrusion of the Cabezon volcanic plug may have remobilized some oil and may have produced or destroyed some structural traps.

La Lena, Empedrado, Chamisa, and Ignacio Chavez WSAs

Sub-area 2 (all 3-C, fig. 8) These four WSAs are all moderately favorable for oil and gas. Known source rocks and reservoir rocks are present under all four areas. These four WSAs are more favorable than the Ojito and Cabezon WSAs because they have a thicker Cretaceous section. It is also less likely that any structures would be flushed by fresh water. There is existing production from Cretaceous and Jurassic rocks within a few miles of both the north and west edges of the San Luis GRA. The drilling density is only about eight tests per township in the San Luis GRA.

Coal

Ojito WSA

Sub-area 1 (2-A fig. 9). There are no known commercial coals within the Ojito WSA, either at the surface or in the subsurface. However, approximately the western third of the WSAs is underlain by Dakota Sandstone which in some areas has thin and impure coals near its base. The favorability is assessed as low (2) and the confidence rating (A) indicates that the available data are inadequate.

In the rest of the Ojito WSA all the known coal-bearing zones are absent. There is direct evidence of the lack of favorability in the form of outcrop and drill-hole data, but such evidence is not abundant because the

outcrops have not been studied in detail.

Cabezon WSA

Sub-area 4 (2-B, fig. 10). The known commercial coals of the Menefee Formation are not present under the Cabezon WSA. However, the Crevasse Canyon Formation crops out in the WSA and there are some commercial coals in the Crevasse Canyon at the Rio Puerco coal field which occurs 15 miles southeast of the Cabezon WSA.

La Lena WSA

Sub-area 2 (4-C, fig. 9). This is the part of the La Lena WSA, the known coal-bearing zones in the lower part of the Menefee Formation (Cleary Member) are present in outcrop and dip to the northwest at about 5 degrees under shallow overburden. The depth to the base of the Menefee Formation is less than 500 feet in this entire sub-area.

Sub-area 4 (2-B, fig. 9). This is the part of the La Lena WSA where the Menefee Formation is absent. The Crevasse Canyon Formation is present in the subsurface and may contain coal resources, especially in the Gibson Coal Member. The depth to the top of the Gibson Coal Member of the Crevasse Canyon Formation is estimated at 400 to 800 feet.

Empedrado WSA

Sub-area 2 (4-C, fig. 9). Comments are the same as for the La Lena WSA, sub-area 1.

Sub-area 4 (2-B). Comments are the same as for the La Lena WSA, sub-area 2, except that the depth to the top of the Gibson Coal Member of the Mesaverde Group is estimated at 0 to 800 feet.

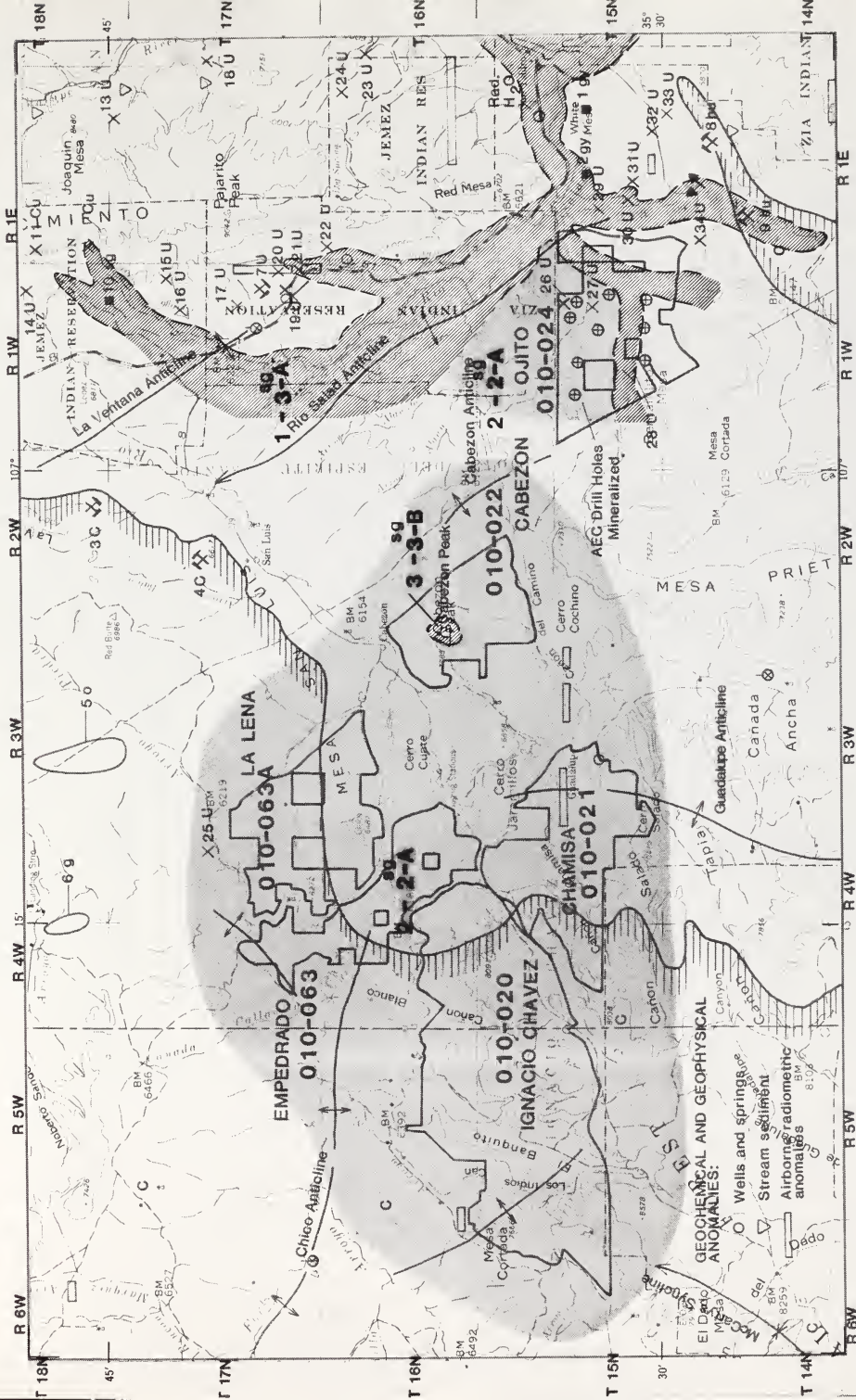


FIG.10 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR SAND AND GRAVEL RESOURCES THE SAN LUIS AREA, NEW MEXICO.

Chamisa WSA

Sub-area 2 (4-C, fig. 9). This is the part of the Chamisa WSA where the known coal-bearing units of the lower part of the Menefee Formation (Cleary Member) are present in outcrop or at shallow depth. The dip is to the west at 5 degrees.

Sub-area 4 (2-B, fig. 9). This is the east end of the Chamisa WSA where the Menefee Formation is absent. The favorability of 2 is based on the possibility of coals stratigraphically lower in the Mesaverde Group.

Ignacio Chavez WSA

Sub-area 2 (4-C, fig. 9). This is the part of the Ignacio Chavez WSA that has the highest potential for coal. The known coal resources are near the base of the Menefee Formation, so the sub-area coincides with the outcrop area of the Menefee from the base to a line where the base of the Menefee is 500 feet deep. The 500 foot limit is somewhat arbitrary but is based on a higher expected mining cost in the area where the lower Menefee coals (Cleary Coal Member) are more deeply buried. The coal beds of the upper part of the Menefee Formation are found only in the northwest corner of the San Luis GRA and are not involved in any of the WSAs. The favorability in this sub-area is high (4) because the coals are known to exist and are actively mined only a few miles away along the strike of the outcrop. The confidence in the assessment is only a "C" because specific information is lacking on the quality and mineability of the beds within this WSA.

Sub-area 5 (3-C, fig. 9). Somewhat arbitrarily (as discussed above) the favorability is downgraded from 4 to 3 in the area where the base of the Menefee Formation is more than 500 feet deep. In the western end of the WSA, the base of the Menefee is presumably less than 500 feet deep but the

classification is unchanged because the coals in that area are poorly known.

Sub-area 4 (2-B, fig. 9). This is the east end of the Ignacio Chavez WSA where the Menefee Formation is absent. There are some possible coal resources stratigraphically lower in the Mesaverde Group but the favorability is much less than in the area of Menefee outcrop.

Sand and Gravel

Ojito WSA

Sub-area 1 (3-A, fig. 10). This sub-area is the part of the Ojito WSA that is along drainages that may have alluvial sand and gravel deposits, and has good access to State Highway 44. The known deposits are along State Highway 44 a few miles east of the Ojito WSA.

Sub-area 2 (2-A, fig. 10). The remainder of the Ojito WSA is classified as low favorability for sand and gravel deposits but there has not been sufficient investigation to properly assess the sand and gravel resources.

Cabezon WSA

Sub-area 3 (3-B, fig. 10). The area of outcropping of Tertiary intrusive rock is classified as 3-B (fig. 10).

Sub-area 2 (2-A, fig. 10). Cretaceous sedimentary rocks underlie the rest of the WSA, resulting in low favorability for sand and gravel.

La Lena, Empedrado, Chamisa and Ignazio Chavez WSAs

Sub-area 2 (2-A, fig. 10). These areas are assigned a low favorability for sand and gravel as they are underlain primarily by sedimentary rocks.

Humates

Ojito WSA

Sub-area 1 (2-B, fig. 11). This is the part of the Ojito WSA where humates may be present at shallow depth in mudstones of the Dakota Sandstone. The favorability is classified as low.

In the rest of the Ojito WSA all the known or likely humate-bearing formations are absent.

Cabazon WSA

Sub-area 1 (2-B, fig. 11). Humates are possible in various units of the Crevasse Canyon Formation but the favorability is classified as low.

In this area of outcrop of Tertiary igneous rock, there is essentially no favorability for humates.

La Lena WSA

Sub-area 2 (4-C, fig. 11). This is the area of outcrop of the (basal) Cleary Member of the Menefee Formation and areas where depth is 200 feet or less to the base of the Cleary. The known coal-bearing zones of varying grade and thickness give the sub-area a high favorability for humates.

Sub-area 3 (2-B, fig. 11). In this sub-area the depth to the base of the Cleary Member of the Menefee Formation is more than 200 feet.

Sub-area 1 (2-B, fig. 11). In this sub-area the Menefee formation is absent but there is a possibility of humates in other formations in the Mesaverde Group.

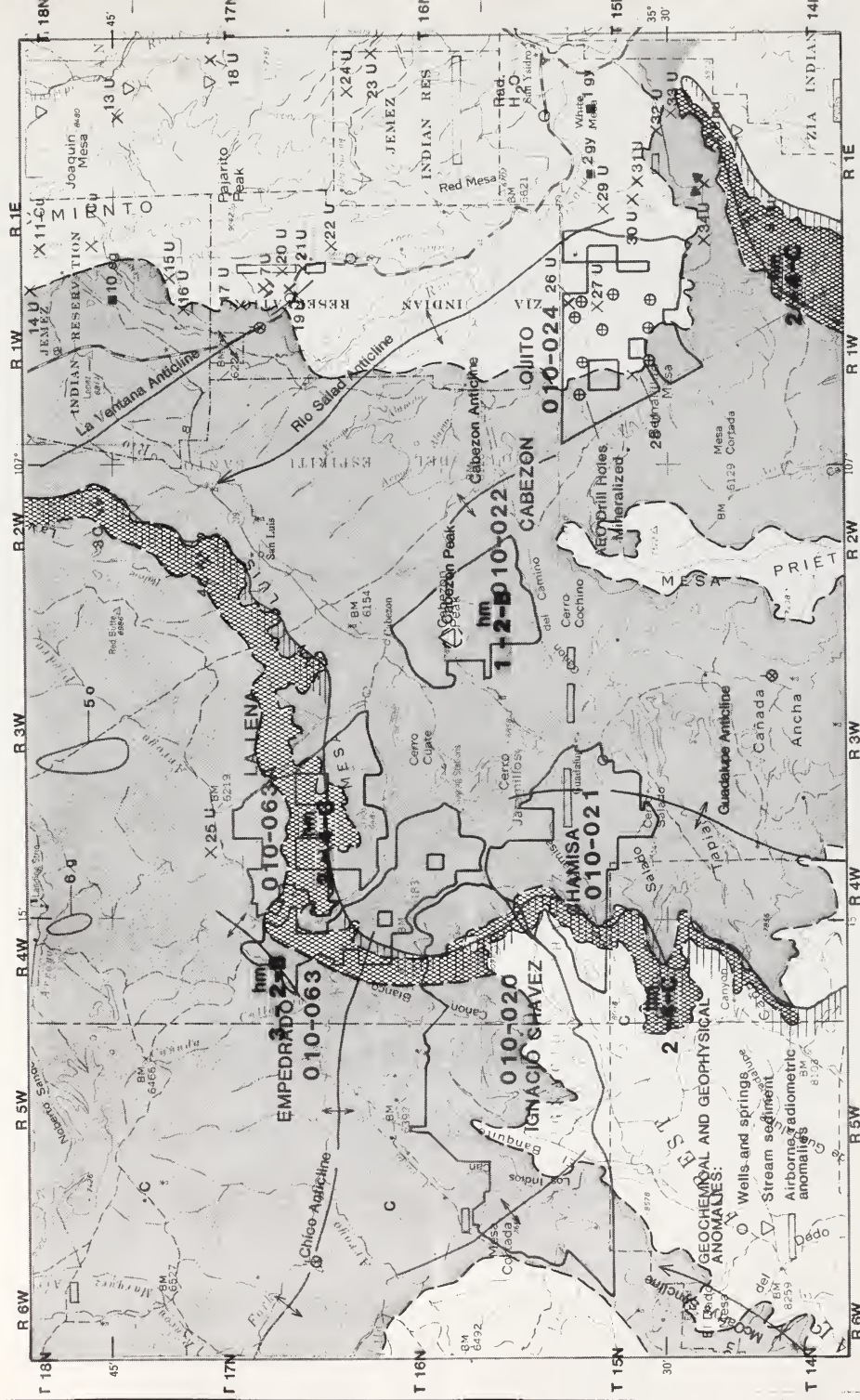


FIG.11 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR HUMATE RESOURCES OF THE SAN LUIS AREA, NEW MEXICO.

Empedrado WSA

The sub-areas in this WSA are classified the same and for the same reasons as the sub-areas in the La Lena WSA.

Chamisa WSA

The sub-areas in this WSA are classified the same as in the La Lena WSA except that part is classified 1-C because the favorable zones in the Menefee Formation are covered by Tertiary basalt.

Ignacio Chavez WSA

In this WSA the sub-areas 1, 2 and 3 (fig. 11) are the same as in the La Lena WSA. In the rest of the GRA the favorable zones in the Menefee Formation are covered by Tertiary basalts or the zones are absent because of a Tertiary intrusive. Additional small areas of Tertiary basalt are not classified separately.

RECOMMENDATIONS

Uranium. Areas of alteration or bleaching near the Nacimiento fault should be mapped, especially in the arkosic sand units of the Westwater Canyon and Brushy Basin Members of the Morrison Formation. Isopach maps of the above-mentioned units should be made, using any available outcrop and drill-hole data.

Copper-Silver. Areas of alteration or bleaching of the Agua Zarca Member of the Chinle Formation should be mapped. Using drill hole data from petroleum exploration holes and other sources, construct isopach maps and tabulate any other available lithologic data on the favorable Agua Zarca Member. Study any drill cuttings and core available from sample libraries.

Oil and Gas. Make isopach maps and structure maps of the known

productive zones in the Mesaverde Group and the Entrada Sandstone. Buy data from commercial services and tabulate in detail the recorded oil and gas shows and past production in and near the San Luis GRA.

Coal and Humate. Construct maps showing depth of overburden and thickness and quality of coal seams in the Cleary Member of the Menefee Formation and the Gibson Coal Member of the Crevasse Canyon Formation. Conduct reconnaissance examination to assess the extent of any coals in the Dakota Sandstone, Gallup Sandstone, and the Dilco Coal Member of the Crevasse Canyon Formation.

Sand, Gravel, and Aggregate. Make reserve and resource estimates, including quality and quantity, using detailed geologic maps and aerial photographs. Make a detailed search for information in files of companies, and county, state, and federal agencies.

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